PACIFIC SOUTHWEST
Forest and Range
Experiment Station

FOREST SERVICE
U.S.DEPARTMENT OF AGRICULTURE
P.O. BOX 245, BERKELEY, CALIFORNIA 94701

CORRELATION OF PLANT MOISTURE IN HAWAII WITH THE KEETCH-BYRAM DROUGHT INDEX

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USDA Forest Service
Research Note PSW-307
1976

Burgan, Robert E.
1976. **Correlation of plant moisture in Hawaii with the Keetch-Bryam Drought Index.** USDA Forest Serv. Res. Note PSW-307, 6 p., illus. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.

Fuel Model A of the U.S. Forest Service's National Fire Danger Rating System provides the basis for rating fire danger in grasslands in Hawaii. The Keetch-Byram Drought Index was tested as a means of monitoring moisture-content fluctuations in brush and grass and at various stages of curing. Linear regressions showed that the Index failed to provide moisture estimates within ± 25 percent, 95 percent of the time. Although the Index can monitor wetting and drying cycles, it is not adequate to provide specific estimates of plant moisture content.

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Retrieval Terms: fire danger indexes; Keetch-Byram Drought Index; fuel moisture content; grasslands; Hawaii.

The basis for rating fire danger in grasslands in Hawaii is provided by Fuel Model A of the National Fire Danger Rating (NFDR) System.[1] The flammability of a fine fuel complex is affected by the proportion and moisture content of living fuel. Use of the NFDR System requires estimates of herbaceous vegetation condition to adjust 1-hour timelag moisture for the presence of moisture in living plants. Fire behavior is highly sensitive to changes in moisture content, so accurate evaluations are important. In addition, estimates of foliage moisture content are needed for fuel models that include brush.

The Keetch-Byram (K-B) Drought Index [2] provides a continuous scale of reference to estimate gains and losses of soil moisture. I tested this Index as a means for estimating (a) herbaceous vegetation condition, as defined in the NFDR System, and (b) actual plant moisture content.

I found that the Keetch-Byram Drought Index provides a useful means of monitoring general wetting and drying cycles, but is not adequate to provide specific estimates of plant moisture content.

THE STUDY

Three grasses and one shrub were investigated: fountaingrass (*Pennisetum setaceum*), introduced to Hawaii in 1926; broomsedge (*Andropogon virginicus*), introduced in 1932; pitted beardgrass (*Andropogon pertusus*), introduced in 1916; and ʻaʻaliʻi (*Dodonaea viscosa*), a native shrub.

Plant moisture was related to the Keetch-Byram Drought Index by regression equations. Two methods were used to estimate plant moisture: (a) assessment of herbaceous vegetation condition for the three grasses, and (b) moisture extraction from periodically collected samples of both fountaingrass and ʻaʻaliʻi.

The herbaceous vegetation condition is the green volume, expressed as a percent of the total volume of the plant. These samples included both green and cured vegetation.

Herbaceous vegetation condition was monitored by means of 300-foot-long transects in each grass type. Two of the four transects were on the island of Hawaii; the other two were on the island of Oahu (*fig. 1*). The percent of the grass plant that was green was estimated at 10 evenly spaced sites along the transect at about bi-weekly intervals, for 17 months or a full dry-wet-dry cycle. The average percent of green of these samples, for each observation date, was then correlated with the Keetch-Byram Drought Index. Weather stations near each transect provided daily maximum temperature and rainfall data.

Three replicate samples of fountaingrass and 'a'ali'i were collected in 500-ml round bottom flasks concurrently with the data on herbaceous vegetation condition. Percent moisture content was determined by the xylene distillation process. Average moisture contents were compared with the Index to determine any correlation.

RESULTS

The herbaceous vegetation condition (expressed as percent green), and the moisture content of fountaingrass (expressed as percent of dry weight) both showed a strong negative relation to the Index as did the herbaceous vegetation condition of pitted beardgrass. However, the herbaceous vegetation condition of broomsedge showed no apparent relation to the Index (*fig.2*).

I found that total rainfall and its distribution at the fountaingrass and pitted beardgrass transects differed significantly from that at the broomsedge transect (*table 1*). At the broomsedge transect, rain showers are frequent enough to prevent development of drought-induced cycles in herbaceous vegetation, although there may be seasonal cycles. Regardless, the buildup of dead plant material is great enough that broomsedge is a major fire problem during periods of dry weather.

Table 1–*Quantity and frequency of rainfall during the sampling period, by vegetation transect*

Species transect	Total rainfall (inches)	Rainy days	Total days observed
Fountaingrass-'a'ali'i	42	112	504
Pitted beardgrass	27	99	466
Broomsedge	101	305	452

The percent moisture content of 'a'ali'i shows a negative relation to the Index (*fig. 2*). 'A'ali'i is less variable in moisture content than fountaingrass. And it responds slower to drying conditions than fountaingrass.

Except for broomsedge, the correlation coefficient of plant moisture to the Index is high for both herbaceous vegetation condition (percent green), and percent moisture content. It ranged from –0.82 to –0.85 (*table 2*).

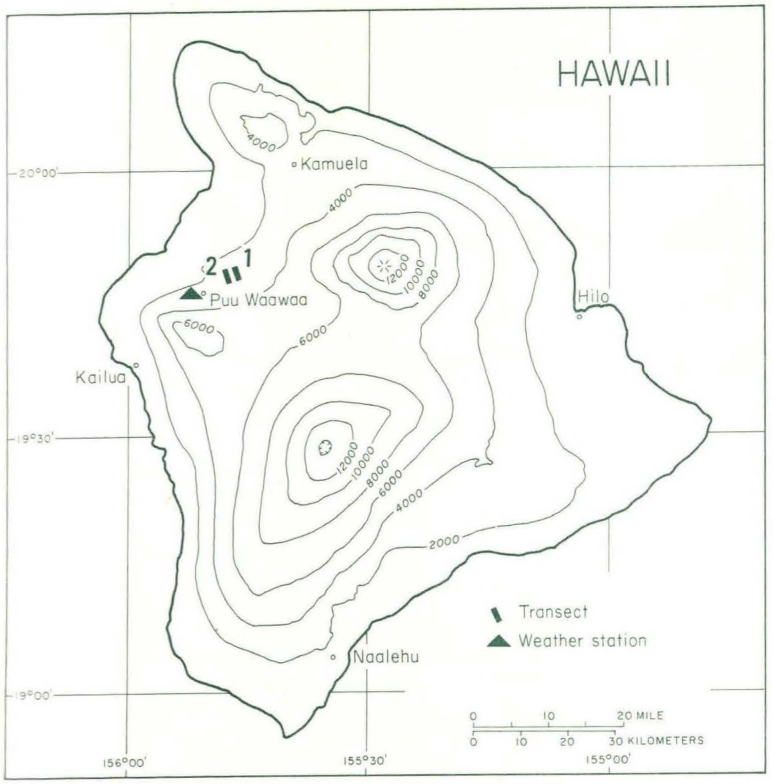
DISCUSSION

Values for percent green were plotted against the Index (*fig. 3*). Slopes of the linear regression lines were compared for the two fountaingrass sites and for the pitted beardgrass site. Each slope was different, and differences were statistically significant at the 5 percent level, suggesting that the relationship between percent green and the Index applies only to a localized area. This application is particularly apparent in the two fountaingrass transects, which are only 1 mile apart. Also, these relationships are probably dependent on species.

I also plotted percent moisture content against the Index (*fig. 3*). Slopes of the regression lines for 'a'ali'i and fountaingrass, at the same site, were significantly different at the 5 percent level. This difference may be the result of individual rooting habits, or may reflect the inclusion of dead stalks and leaves in the

Table 2–*Statistics for linear regressions illustrated in figure 3*

Plant	Site	N	$\bar{X}$	S_x	$\bar{Y}$	S_y	r	r2	$\hat{Y} = a + bx$	
									a	b
Fountaingrass	1	35	380.3	221.0	19.9	19.4	–.85	.72	48.3	– .0748
Fountaingrass	2	25	324.7	239.4	18.6	11.6	–.83	.68	31.7	– .0401
Pitted Beardgrass	3	30	448.6	262.7	24.9	34.7	–.84	.71	74.6	– .1107
'A'ali'i	1	35	380.3	221.0	140.8	44.5	–.82	.68	203.9	– .1660
Fountaingrass	1	35	380.3	221.0	108.3	78.5	–.84	.71	222.0	– .2990
Broomsedge	4	28	245.1	156.5	31.6	6.9	–.21	.04	29.3	+ .0093



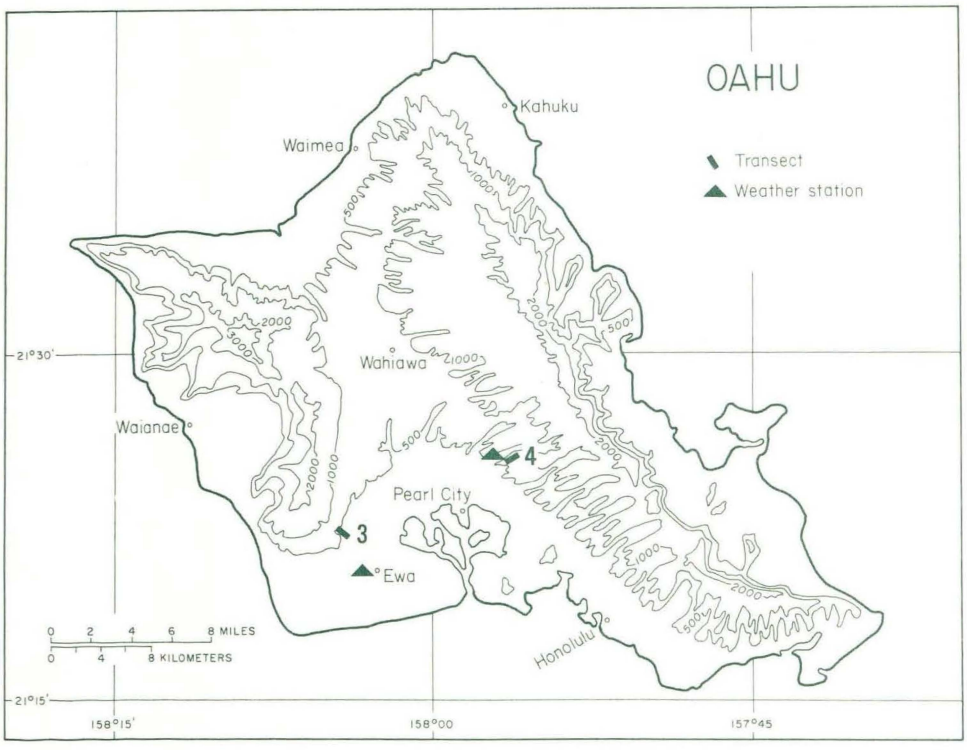


Fig. 1—Two of the four study transects were on the island of Hawaii: No. 1 sampled fountaingrass; No. 2 sampled fountaingrass and 'a'ali'i. The other two were on the island of Oahu. They sampled pitted beardgrass, No. 3, and broomsedge, No. 4.

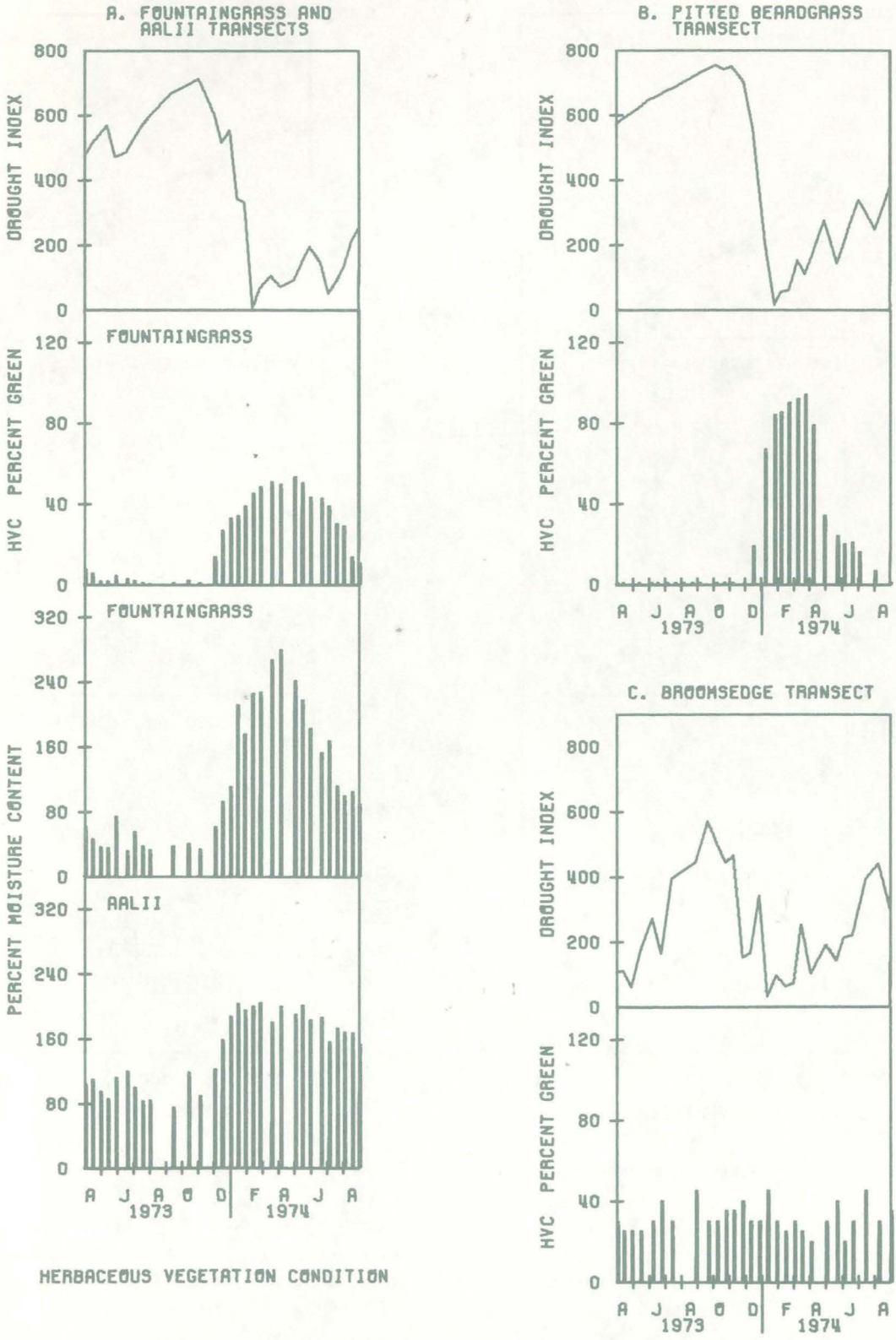


Fig. 2—Relation of plant moisture to the Keetch-Byram Drought Index.

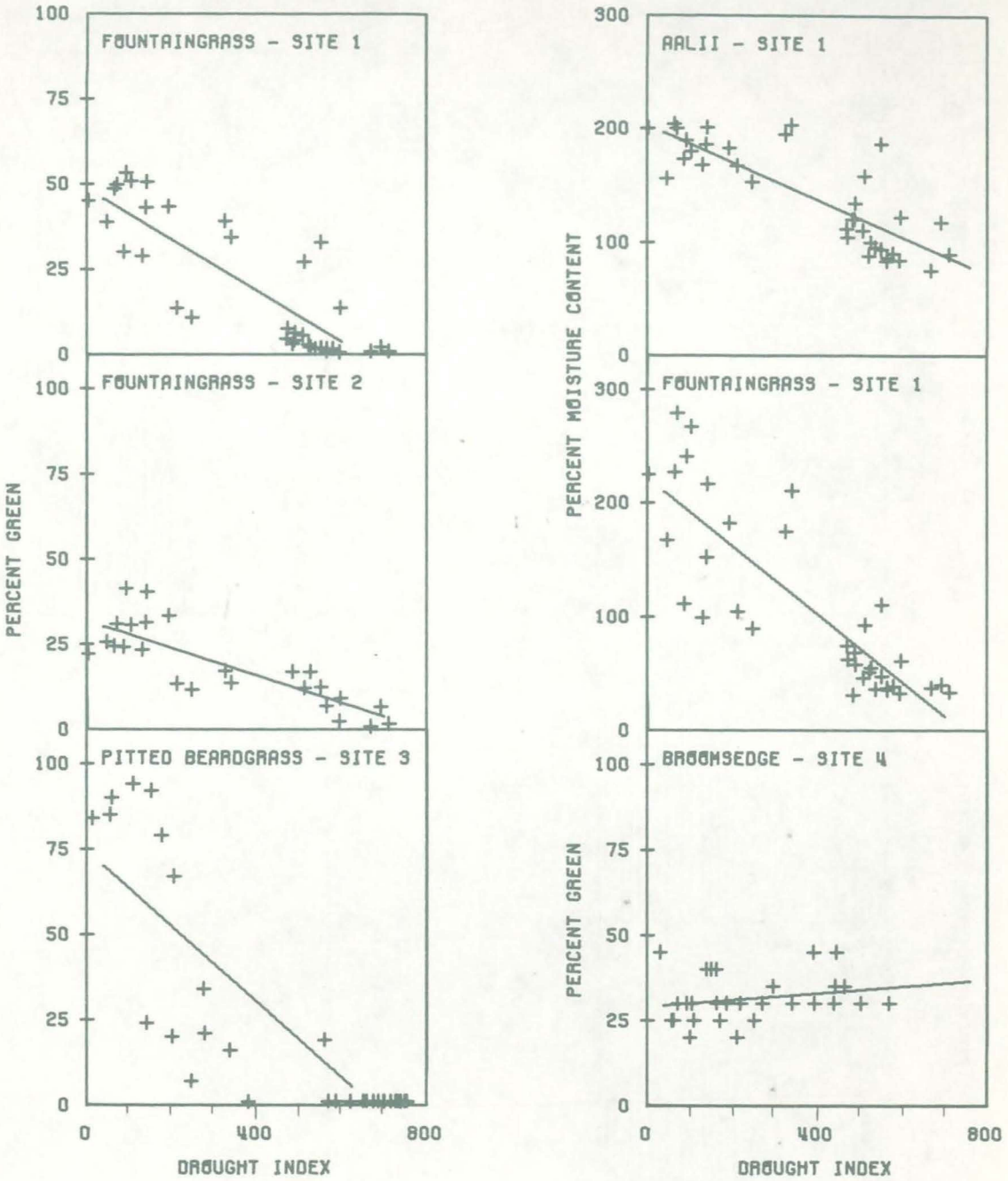


Fig. 3—Regressions of plant moisture on the Keetch-Byram Drought Index.

fountaingrass samples. The ʻaʻaliʻi bushes had few dead leaves.

Only one regression analysis did not provide statistically significant results. And that was from the plotting of percent green against the Index for the broomsedge transect (*fig. 3*).

Recent work suggests that when the moisture content of living plants becomes a measured quantity within the NFDR System, the estimates of moisture content would be useful if they were within ±25 percent of the actual value, 95 percent of the time.[4]

The regression of the percent moisture content of ʻaʻaliʻi leaves on the Keetch-Byram Drought Index does not provide the actual moisture content of the leaves, as determined by xylene distillation, within ±25 percent, 95 percent of the time. The regression

of fountaingrass moisture content on the Index also failed to provide this information. Similarly, none of the regressions of percent green on the Index were accurate within these limitations.

NOTES

[1] Deeming, John E., James W. Lancaster, Michael A. Fosberg, R. William Furman, and Mark J. Schroeder. 1972. *The national fire-danger rating system.* USDA Forest Serv. Res. Paper RM-84, 165 p. Rocky Mountain Forest and Range Exp. Stn., Fort Collins, Colo.

[2] Keetch, John J., and George M. Byram. 1968. *A drought index for forest fire control.* USDA Forest Serv. Res. Paper SE-38. 33 p., illus. Southern Forest Exp. Stn., New Orleans, La.

[3] Personal correspondence with James W. Lancaster, Boise Interagency Fire Center, Boise, Idaho, March 1975.

The Author

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